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Drying of Protein Ingredients
"How to get optimal product performance with minimal costs"

Drying is one of the key processes to produce protein ingredients or protein containing food products with a long shelf life. The drying process determines to a great extent the physical (handling and stability) and sensory properties and microbial shelf life stability of the protein product.
At NIZO food research, drying of protein products is a key expertise, and since we celebrate the 50th anniversary of our Protein Centre, we would like to share some of the approaches we use with you and show what kind of solutions are possible. In general we see three types of drying projects:

1. optimization projects to reduce processing costs
2. projects to improve product quality in the broadest sense. This includes projects related to handling properties, or improvement of organoleptic quality or safety related projects.
3. test productions to produce powder at a pilot scale level.

Reduce Processing Costs

Processing costs determine the costs of the final product and the related margins to a large extent. Therefore, process optimisation is often a continuous development in order to remain competitive. Over the years we have developed a dedicated software platform for modelling the effect of processes on product properties. This has proven to be a great help in process optimisation. It is, for example, possible to calculate the amount of protein denaturation and microbial inactivation in a pasteur, to retain as much native protein in the final powder at given microbial levels.

The combination of industrial expertise and predictive models (Premia: PREdictive Models for Industrial Application) is often applied in the optimisation of spray dryers for all kind of food products. Experts perform an inspection of the spray dryer to be optimised and relevant product properties like sorption isotherms are often measured. This combined information can be implemented in Premia and optimal conditions (e.g. highest capacity and the product within specification or an optimal product quality) are determined. It is our experience that these projects often lead to easy-to-implement solutions with a high return on investment.

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Sometimes, manufacturers are looking at more significant improvements. In this case, increasing the dry matter content of the feed is very interesting. Drying processes often involve an evaporation step in advance of spray drying. An evaporator is up to ten times more energy efficient than a spray dryer. Therefore, it is attractive to remove as much product as possible by evaporation before drying the product. The gains can be quite high; an increase of the dry matter content of the feed to the spray dryer of 2% already translates to an energy reduction of 6% and a capacity increase of the spray dryer of 9%! Usually, the dry matter content of the feed is limited by the viscosity. A higher viscosity can result in a complicated atomization behaviour and worse drying behaviour. Therefore, the optimal solution for a process line will very much depend on its specific characteristics (e.g. layout of the current process, physical constraints, automation of the process, product characteristics). In any case, testing and challenging the process for a specific product at increased dry matter content before implementation is crucial. Our experience has shown that these tests should both involve the evaporation and the spray drying process, since both unit operations can be limiting in implementation. In our experience it is possible to design robust industrial processes that run more efficiently at a high dry matter content with the combination of pilot testing, lab analysis, advanced modelling tools and industrial expertise.

Powder analyses are relevant for optimisation of drying. These include bulk density measurements, insolubility index (ISI), particle size distribution, glass transition temperatures, stickiness measurements and water sorption isotherms. The latter two are

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often applied in the optimization of spray dryers with regard to fouling. When powder particles are sticky when hitting the wall of a spray dryer, they can cake to the wall, forming a fouling layer, which can start to smoulder and be a source of explosions. Therefore, fouling should be avoided. In addition, run times are reduced, since the fouling layer needs to be physically removed thus causing down-time of the equipment. These phenomena often occur with powders containing large amounts of small molecules, like amino acids or sugars. In a stickiness measurement, it is determined at which temperature-moisture content combinations a powder becomes sticky. These measurements can be combined with a water sorption isotherm analysis (which describes the water content of a powder at different air humidities and temperatures). Using NIZO Premia spray dryer models, optimal conditions can be determined at which no fouling will occur, while running at optimal capacity. In addition, smouldering properties of the powder can be investigated to stretch the process at safe conditions even more.

Product quality improvement

Product quality is largely determined by product composition and applied processing conditions. For example, lumping of powders during storage is a common problem for powder manufacturers. Lumping can, amongst others, be caused by temperature changes or in dairy products by lactose crystallization. Analysis of the powder properties and structure at a microscopic level and measurement of the stickiness properties helps in finding solutions for lumping.

Off flavour formation is an undesired side effect of drying processes. Food products that contain both proteins and sugars (e.g. dairy products) have a tendency to form a caramellic or a burnt-roast (brown) related flavour to the product as a result of Maillard reactions. A lot of spray-dried food products based on protein powders, such as for example infant formula, usually also contain fat. In addition to the Maillard there is also a risk of oxidation related off flavours. Oxidation of fat can also occur during storage, whereby the off flavours (e.g. fishy, cardboard, painty) can intensify or change along the shelf life. A suitable process design helps in avoiding or minimizing these undesired side effects. The combination of process optimisation expertise, shelf life testing and sensory evaluation expertise is essential to create optimal product quality for minimal costs.

Powder flowability , bulk density and solubility are to a large extent determined by the agglomeration of the powder. Agglomeration is for a large part influenced by the atomization of the powder in the spray dryer and the flow patterns in the spray dryer.

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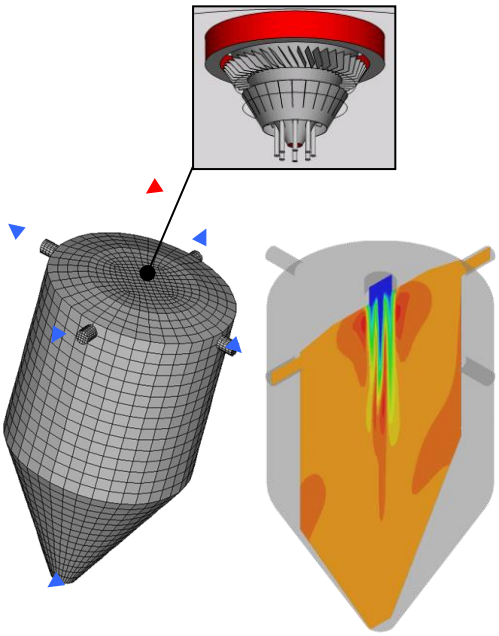
Agglomeration behaviour can be improved by examination of the atomization behaviour. This can be done by a.o. measuring the droplet size distribution inside the spray dryer. A careful selection of nozzles, processing conditions and product characteristics will enhance control over the powder properties.

In addition, in our experience, a careful examination of the flow in the spray dryer by computational fluid dynamics (CFD) calculations is very suitable to reduce fines, improve agglomeration, reduce fouling of the walls and improve energy efficiency. The CFD calculations show in great detail where particles are flowing within a spray dryer and what their properties (e.g. water content, which relates to stickiness) are. This way, we have been able to find the cause of fouling which was occurring at specific places in a spray dryer, something which is not possible with visual techniques, since the spray dryer cannot be examined internally when running.



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Pilot plant

At NIZO we have the enormous advantage of having the availability of a large variety of drying equipment in our pilot plant. The equipment is available for process and product development but also for toll manufacturing. For (new) process development we regularly collaborate with external partners. As an example, NIZO and GMF Gouda, a leading drum dryer equipment manufacturer, have recently developed a pilot scale vacuum drum dryer. With this equipment, it is possible to dry products on a drum dryer at lower temperatures. The low temperatures allow drying of heat sensitive components, like specific proteins or enzymes. At the moment a first upscaled version of this vacuum drum-dryer is being installed. Shortly it will be available for process and product development tests of food grade materials.

Besides process development the facilities are regularly used for producing test batches, for example for products in a development stage or for the pre-marketing stage of new ingredients, or for producing samples for exhibitions or safety or clinical studies where a customer does not want to interrupt it's main production processes. Also toll manufacturing of high value ingredients is carried out. Especially where multiple unit operations like heating membrane separation, falling film evaporation and drying are involved.

Concluding, tuning powder properties and reducing processing costs is to our experience possible with a balanced mix of industrial experience, dedicated analytical tools, a variety of relevant pilot scale equipment and predictive modelling tools. By combining the different expertises it is possible to create optimal product quality with minimal costs.

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About NIZO food research
NIZO food research is one of the most advanced, independent contract research companies in the world.
We apply our expertise and competitive technologies to support your:

- Innovation (flavour, texture, health)
- Cost reduction (process efficiency, ingredient replacement & test productions)
- Responsible entrepreneurship (food safety & quality, sustainable processing, evidence based health claims).

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